International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 07 | July 2020 www.irjet.net p-ISSN: 2395-0072

Managing Construction Material Waste on Building Sites with Building Information Modelling

Timothy Olubanwo Adewuyi[1]*, Etorobong Kenneth Umoren[2]

[1]*Senior Lecturer, Department of Building, University of Uyo, Uyo, Nigeria*
[2]*Postgraduate Student, Department of Building, University of Uyo, Uyo, Nigeria*

Abstract - *The volume of material waste generated during the delivery of a constructed facility is the reflection of the expertise and conformability to conventional practices. This study emanated from the necessity of capturing the currency of utilising Building Information Modelling (BIM) for construction material waste management (CMWM) on building sites to enhancing the sustainability of the built environment in the study area. The survey research approach was adopted with a structured questionnaire, while the data were analysed using the relative level of use index and mean score. The assessment of the level of use and the potentials offered by BIM tools for CMWM, as perceived by the Architectural, Engineering, and Construction (AEC) professionals in the study area, is revealing. The findings revealed that material standardisation, dimensional coordination, and waste causes identification were mostly the concerns of the professionals while using BIM. The potential of BIM is mostly perceived in the aspects of clash detection, detecting illogical designs, and 3D control and planning to reduce waste in the study area. The use of BIM for CMWM varied significantly among the selected States in the South-South region of Nigeria for the study. The study concluded that the use of BIM for CMWM had not gained ground in the study area. Therefore, this study recommended the use of BIM for project delivery in the study area to derive the benefits it offers, especially for CMWM.*

Key Words: *BIM; building site; construction material waste management (CMWM); construction material waste; illogical design; material standardisation; reduce waste.*

1.INTRODUCTION

The sustainability of the built environment depends much on the volume of materials generated during new construction and retrofit activities. In contrast, the quantity of waste generated is the reflection of the expertise and conformability to conventional practices exhibited by stakeholders involved. Whereas the developed countries are driving towards zero waste, the developing ones seem nonchalant to sustainable practices with little or no effort for improvement. A recent study reported that Building Information Modelling (BIM) offers numerous befits [1]. Nonetheless, it is understood differently by different users, and its deployment is incompatible with all organisations because of contrasts in company philosophies, techniques, size, establishment objectives, and goals [2]. Consequentially, there have been many different definitions of BIM depending on the user's understanding and its application. However, this study relies on the definition of Eastman *et al.* [3], which viewed BIM as the mix of both innovative tools and an inclusive project delivery process, utilised in improving project procurement and aimed at advancing cooperation between experts in the building industry. Shreds of evidence abound from extant literature that many causes and diverse stakeholders contribute to the generation of material waste in construction and engineering works [4, 5, 6, 7].

Akinade *et al.* [8] revealed six categories of evaluation criteria for construction waste management tools, which include the tool's ability to predict waste potentials, availability of waste data, Building Information Modelling, design considerations, commercial and procurement, and consideration of technology. The existing construction waste management (CWM) tools assessed by the study attested to the performance of the evaluation criteria they were not robust enough to combat construction waste. To this end, it informative in consonance with previous studies that the construction industry is still under undue pressure to arrive at a more robust technique to help minimise the ever-escalated waste production from construction sites [9]. However, BIM is a more reliable technology that is capable of numerous benefits in the construction industry, including solving the problem of waste on building sites at any stage of the construction [10]. BIM, as an advanced modelling philosophy, is useful in many building-related productions, including designs visualising, taking off of quantity, ability to check regulations compliance, and process of scheduling in construction. BIM is also capable of helping project stakeholders to attain waste minimisation for building construction throughout the lifecycle of the building in a collaborative way through improving building construction performance.

Many studies in the past decade focused on the utilisation of BIM towards reducing the generation of waste for new constructions, retrofit, and demolition works [11, 12, 13, 14, 15, 16]. However, no local study is known to have established the level to which the AEC professionals have used BIM for managing construction material waste and their ostensibility of reducing construction waste with the benefits provided by BIM. Consequently, to comprehend the criteria for viable waste minimisation with BIM, this research approaches the issue from a phenomenological viewpoint.

Hence, the question remains: To what level has the practice of utilising BIM for construction material waste reduction been embraced by stakeholders in this study area? To what extent can BIM be used to manage material waste on construction sites? The two objectives that guided this study are to:

i. Assess the level of use of BIM for evaluating the occurrence of construction material wastes in building projects in the study area;
ii. Evaluate the potentials of BIM for construction waste management on building construction sites in the study area;

Additionally, two hypotheses were also postulated, with each accruing from the two objectives, respectively. These two hypotheses were captured in the null version as follows:
Ho_1: There is no significant variation in the mean responses to the level of BIM's usage for evaluating construction waste occurrence among the selected States in the study area;

Ho_2: There is no significant variation in the mean responses to the potentials of BIM for construction waste management on building construction sites among the selected States in the study area.

1.1 Concept of BIM for Evaluating Construction Wastes Occurrence

Building Information Modelling (BIM) is the use of computer-generated models to simulate the planning, design, and construction of projects. It is a concept that is transforming the construction world internationally in the course of revolutionizing the construction industry due to its robust platform for collaboration, interoperability, integrated project delivery, and knowledge sharing, among others [3]. The richness of a BIM system depends on the value of data integrated into it, and over the last few decades, the pattern of the relationship among the BIM systems are studied continually by scientists with the application of new dimensions to achieve a maximum result. BIM is used to develop a collaborative construction process that includes design, build, operate, and maintenance of buildings. However, the adoption of BIM in Nigeria is very slow; it is used mostly for schematic design and presentation of drawings scantly by Architects and Engineers. Onungwa and Uduma-Olugu [17] showed that BIM has a high impact on client satisfaction, time for completion, quality, and presentation of different concepts in schematic design. It also showed a high impact on conflict resolution, supervision, construction programming, and quality of completed jobs during the post-contract stage.

The definition of BIM carries different terms relating to model, design data, and construction management. Sacks *et al*. [18] defined BIM from a three-dimensional (3D) perspective as an approach to building construction and design that involved 3D parametric modelling of building for detailing and design and computer-intelligible exchange of building information between design, construction, and other disciplines. From a design and project data management standpoint, BIM is a process of generating and managing building data during the building's life cycle and uses three-dimensional (3D) real-time, dynamic building modelling software to increase efficiency in building design and construction [19]. In a construction management perspective, Eastman *et al*. [3] defined BIM as an intelligent simulation of architecture aimed at achieving an integrated project delivery. Within the context of this research, BIM is defined as a real-time interactive and collaborative communication system, which has the potential of helping project stakeholders to collaboratively attain construction waste minimisation throughout the whole lifecycle stages of a building by improving building construction performance.

No matter the definitions given to BIM, the goal and purpose of BIM include detailed and complete replication of a building or other BIM compliance project in a digital environment to provide a platform for collaboration and management of information throughout the lifecycle of a facility [20]. At the construction stage, the project team can use BIM for monitoring project's progress, stakeholders' meetings, change orders and punch list information in the BIM models, and information extraction and coordination by contractors and subcontractors at sites.

1.2 Evaluating Construction Wastes Occurrence with BIM Technology

BIM helps project participants improve the technologies in the planning, design, construction, and demolition phases, thereby managing construction waste efficiently [13]. Extant studies have averred that wastes generation is much at the construction stage of building construction compared to preconstruction and post-construction stages. However, waste minimisation is mostly useful at the design stage to aid the efficient reduction of waste accumulation to the construction stage. Agapiou *et al*. [21] recommended that effective minimisation of construction waste should start at the design stage before the result is affected at the construction stage. In consonance, Akinade *et al*. [11] enunciated the necessity of effective decision-making mechanisms at the design stages to reduce the effect of design changes on material wastage. Philosophies for designing out waste such as design for material optimisation, design for recovery and reuse, design for waste-efficient procurement, design for off-site construction, as well as design for deconstruction and flexibility were articulately encouraged for incorporation into designs. However, Akinade *et al*. [8] appraised the performance of existing construction waste management tools and employed the outcomes to develop a comprehensive BIM framework for managing construction waste. The criteria postulated by the study, presented in Table 1, can be used to evaluate the level to which professionals in the Architectural, Engineering, and Construction (AEC) industry employ BIM to reduce the incidence of material wastage in project delivery.

Table -1: Criteria for Evaluating Construction Wastes Occurrence with BIM Technology

Group	Criteria
Waste Prediction	Waste origin consideration
	Waste causes identification
	Waste prediction from design
	Accurate waste estimation
	Universal waste-quantification model
Data	Interface for waste data collection
	Transparency in data collection
	Sufficient waste data
	Accurate waste data capture
	Segregated waste data
	Accessible waste database
	Universally applicable data
	Machine-readable knowledge base
BIM	BIM compliance
	Visualization and reporting
	Project lifecycle consideration
	Design-centric consideration
	Collaboration among stakeholders
	Open standards support
	Interoperability with design software
Technology Related	Decision support functionality
	Location-based services
	Cloud computing support
	Application programming interface (API)
	RFID support
Design	Dimensional coordination
	Automatic capture of design parameters
	Design optimization
	Buildability consideration
	Real-time waste analysis
	Design standardization
	Clash detection
	Design out waste principles considerations
Commercial and Procurement Related	Cost-benefit analysis
	Supply-chain engagement
	Schedule integration
	Procurement process coordination
	Access to suppliers' database
	Robust materials database
	Materials standardization

Source: Akinade *et al.* [8]

BIM finds its application in waste visualisation and reporting, dimensional coordination, material standardisation, the waste prediction from design model, interface for waste data collection [14]. BIM becomes essential in dimensional coordination providing the precise dimensions and locations of the components needed for prefabrication, and the information derived can be translated into measuring units such as metres and its sub-units and then digitalised into coordinates [22]. Adewuyi and Odesola [23] concluded that the level to which a construction firm generates waste might be a result of the structure, culture, practices, policies, and size of the construction firm. Ayarkwa, Agyekum, and Adinyira [24] believed that for the reduction of waste on sites, construction firms should embrace material waste minimisation strategies. The findings of several studies [23, 25, 26, 27] from different countries indicated that the level of materials waste generation for construction projects ranges from 1 – 30%. However, the achievable level of reduction of construction material waste on building sites with the use of BIM remains a gap in research studies.

1.3 Efficacies of BIM for Construction Waste Management

Some authors believe that construction waste management could be supported and enhanced through the use of BIM. Few studies have made efforts to investigate the use of BIM to harness construction waste generation on building sites [11, 28, 29]. Those studies concluded that BIM has the potential to assist designers to minimise waste on their projects by limited, but growing body of recent literature. Won, Cheng, and Lee [28] postulated the use of BIM as an effective means to reduce the amount of construction and demolition waste through improving the quality and accuracy of design and construction and minimising design errors, rework, and unexpected changes. The study demonstrated, through case studies, that BIM-based design validation could minimise up to 4.3–15.2% of construction waste that might have without using BIM been generated. It is, therefore, a possible solution for eliminating the major causes of construction waste that arise during both the design and construction stages. According to the study, the proposed use of BIM like the validation of designs, quantity take-off, phase planning, and site utilisation planning, amongst others, were for the reduction of construction waste. BIM can also enable the minimisation of the amount of construction and demolition waste by improving the quality and accuracy of design and construction, thereby reducing design errors, rework, and unexpected changes. The use of BIM can reduce improper design, residues of raw materials, and unexpected changes in building design and improve procurement, site planning, and material handling in construction management. Ahankoob *et al.* [10] listed the essential BIM solutions for waste reduction to include conflict, interference and collision detection, construction sequencing and construction planning, reducing rework, synchronizing design and site layout, detection of errors and omissions (clash detection) and precise quantity take-off. The potentials of BIM for CMWM, which can be utilised at the construction stage of building project delivery, as identified by various past studies, are shown in Table 2.

Suggestions by numerous literature indicate that there is a need to investigate the effects of adopting information and communication-related strategy, of which BIM fall under this category, to assist in managing building construction waste during design and construction stages [18, 30]. In Liu *et al.* [29], many respondents observed that they have been able to detect clashes in their projects through the application of BIM, which has helped to overcome ineffective coordination and communication. Additionally, the study found that coordination and communication through a shared 3D standard model, design, and project reviews can be enhanced by coordinated design documentation, which reduces waste caused by lack of coordination of detail design, thereby overcoming ineffective coordination and communication.

Table -2: BIM Uses for Construction Material Waste Management (CMWM)

BIM's Potentials for CMWM	Reference
Support for waste management innovations	Akinade *et al.* (2018); Akinade *et al.*, (2016)
Improved materials classification methods	Akinade *et al.* (2018);
Automatic generation of waste-related documents	Akinade *et al.* (2018);
Interoperability among waste management tools and BIM software	Akinade *et al.* (2018); Bilal *et al.* (2016)
Early supply-chain integration for sourcing and supply for waste management decisions	Akinade *et al.* (2018); Won & Cheng (2017); Liu *et al.*, 2015
Support for whole-life waste analysis	Akinade *et al.* (2018); Bilal *et al.* (2016); Liu *et al.*, 2015
Use of 3D printing for prefabrication	Akinade *et al.* (2018); Won & Cheng (2017)
Phase planning (4D simulation)	Won & Cheng (2017)
Quantity take-off (cost estimation)	Won & Cheng (2017); Liu *et al.*, 2015
3D coordination of building models to reduce waste (clash detection)	Akinade *et al.* (2018); Won & Cheng (2017); Liu *et al.*, 2015
Site utilization planning	Won & Cheng (2017)
Construction system design	Won & Cheng (2017)
3D control and planning	Won & Cheng (2017)
Existing conditions modelling	Won & Cheng (2017)
Record modelling	Won & Cheng (2017)
Create 2D Drawings	Won *et al.* (2016)
Create BIM models	Won *et al.* (2016)
Perform O & M review	Won *et al.* (2016)
Detect illogical designs	Won *et al.* (2016)
Perform constructability review	Won *et al.* (2016)
Detect discrepancies	Won *et al.* (2016)
Detect omissions	Won *et al.* (2016)
Modify BIM Models	Won *et al.* (2016)
Perform collision detection	Won *et al.* (2016)
Generate BIM reports	Won *et al.* (2016)
Identify Solutions to Collisions	Won *et al.* (2016)
Computer-aided visualisation and simulation of waste performance	Akinade *et al.,* (2018); Bilal *et al.* (2016); Liu *et al.* (2015)
Improved coordination and communication	Liu *et al.* (2015)
Detailing	Liu *et al.* (2015)
Digital fabrication	Won & Cheng (2017); Seyis (2019)

Love, Lopez, and Edwards [31] asserted that there is an agreement on the potential use of BIM for construction waste management during design stages, including clash detection for error reduction. The practice of purchasing extra materials to make up for wastage during construction predisposes construction projects to cost and time overruns, sub-standard works, disputes, and abandonment of projects [32, 33]. Seyis [1] explained some of the unique benefits of BIM to include its potential to decrease the total cost of projects, increase productivity and quality as well as reduce conflicts in projects delivery. Hence, wastage in terms of material, time, and cost can be overcome [34].

2. RESEARCH METHODOLOGY

The study adopted a survey design approach. At the onset of the study, recent studies extensively reviewed were related to the application of BIM to construction material waste management (CMWM) on building sites to capture the required variables for the study. Forty (40) criteria were sourced for assessing the level of use of BIM technology for CMWM. At the same time, fifty-five (55) variables were extracted with notations against each one to indicate their applicability to CMWM at different levels of building project procurement vis a vis planning, design, construction, operation, and demolition stages. These were presented to seven practicing AEC professionals and three academics for evaluation and pilot testing for content validity of the variables to ensure that all the essential items were included and undesirable items were eliminated in the research instrument [35]. The content validity ratio (CVR) formula by [36] was used to decide the number of factors to retain in the research instrument for the study. According to [35], CVR is a linear transformation of an equivalent level of agreement on how many "experts" within a panel rate an item "essential," which is calculated based on the expression in Equation 1.

$$\mathrm{CVR} = \frac{n_e - \left(\frac{N}{2}\right)}{\frac{N}{2}} \qquad (1)$$

where, CVR is the content validity ratio; n_e is the number of panel members indicating "essential," and N is the total number of panel members. The final evaluation to retain the item based on the CVR depends on the number of panels. Each item was assessed using a three-point scale (not necessary, useful but not essential and essential). Nineteen (19) of the criteria for evaluating the level of use of BIM were retained while the ones for assessing CMWM on building sites with the utilisation of BIM were reduced to twenty-eight (28), being the ones that can be used at the construction stage. These decisions were based on the calculated CVR range of 0.56 - 0.79, according to the guideline for the valid value of CVR for the evaluated item to be retained [35].

The AEC professionals, who are familiar with the use of BIM technology, were the targets of the study. This study obtained its population from the listings of the professional bodies in the study area comprising of registered building construction professionals such as Architects, Builders, Quantity Surveyors, and Engineers practicing, employed or residing within the selected States of Akwa Ibom, Cross River and Rivers in the South-South geopolitical zone of Nigeria as presented in Table 3. These three States were selected because there are more ongoing standard construction projects like the Exxon Mobil Headquarters Building (21-storey) in Akwa Ibom State and the construction of the second Terminal Building at the Victor Attah International Airport is ongoing. Secondly, Port Harcourt in River State is a metropolitan city housing the headquarters of many oil companies and many oil servicing companies with many ongoing building projects. Summarily, the presence of oil-producing giants influences the standard of professional practice positively in the selected States than other States within the zone.

Table -3: Sample size of Each Component of the Population Frame

Registered Professionals	Akwa Ibom			Rivers			Cross River		
	N	n_1	n_i	N	n_2	n_i	N	n_3	n_i
Architects	49	84	18	65	112	24	34	62	13
Builders	25		9	30		11	18		7
Engineers	110		40	145		53	86		32
Quantity	47		17	68		25	32		12
Total	**231**		**84**	**308**		**113**	**170**		**64**

Total population = 709; Sample size, n = 256; $n_1 + n_2 + n_3 = 258$; Total stratified sample size = 261; n_1, n_2 and n_3 are the stratified sample size based on State; n_i is the stratified sample size based on profession.

In the determination of sample size, the Taro Yamane formula was applied to a total population of seven hundred and nine (709) professionals, using the expression in Equation 2, which are distributed across the three selected States of Akwa Ibom, Cross River and Rivers.

$$n = \frac{N}{1 + N(e)^2} \qquad (2)$$

where:
n is the sample size;
N is the finite population;
e is the level of significance, and 1 is unity;

This study employed a stratified random sampling method to source for the necessary data for the study. The respondents were stratified into three groups based on their State of residence or official address/location within the South-South geopolitical zone (the study area) in Nigeria. The stratification was necessary to decipher the extent to which level of use of BIM and employment of BIM for CMWM vary among the selected States. The stratification yielded 258 as a sample size. To include all significant sub-population and precision [37], the proportionate type of stratified random sampling was adopted based on the expression in Equation 3 for stratifying the sample size into their respective professions. The result further increased the sample size slightly to 261.

$$n_i = \frac{nS}{N} \qquad (3)$$

where:
n_i is the sample size in each State;
n is the total sample size derive from Equation 1;
S is the corresponding population in each State;
N is the total finite population.

A structured questionnaire comprising three (3) sections was the instrument of the research. The first section elicited the demographic attributes of the respondents, such as their professional designate and affiliation, years of experience, and specifically, duration of familiarity with the use of BIM technology. The next section sought data on the level of use of BIM technology for the management or reduction of CMW at the construction stage of project delivery. The last section determined the potency of BIM for managing and minimising construction material waste on building sites. Five-point Likert scale was employed for measurement of the level of use of BIM for CMWM and to determine the potentials of BIM technology for CMWM. The questionnaires were self-administered and through research assistants. The number of questionnaires administered was 300, which is above the calculated sample size by about 15%, as the researcher was conscious of catering for non-return by some respondents.

The reliability tests conducted to establish the internal consistency of the research instrument yielded Cronbach's alpha (α) coefficients of 0.961 and 0.967 for sections 2 and 3, respectively, which fall at a top category. Taherdoost [35] reported four cut-off points for reliability test, which includes excellent reliability (0.90 and above), high reliability (0.70-0.90), moderate reliability (0.50-0.70), and low reliability (0.50 and below). The "*Cronbach's alpha if item deleted*" of each variable was examined. The examination aimed at authenticating that all the variables contribute to the internal consistency of the data. Akinade *et al.* [11] asserted that it is a good practice to delete variables whose "*Cronbach' alpha if item deleted*" is higher than the overall coefficient to improve the overall reliability of the data. However, none of the factors in this study was deleted. All the 28 variables were ranked using the descriptive statistical mean as a ratio of importance. The responses to the questionnaire survey were subjected to statistical analysis using Relative Level of Use (RLU), based on Equation 4, for the level of use of BIM technology for CMWM. The mean score technique was used for computing and ranking the potentials of BIM for as shown in Equation 5, while the Kruskal Wallis H test was used for testing the two hypotheses.

$$\text{Relative Level of Use (RLU)} = \frac{\sum W}{A * N} \qquad (4)$$

and;

$$\text{Mean Score (MS)} = \frac{\sum W}{N} \qquad (5)$$

where:
W is the weight given to each factor by the respondents and ranges from 1 to 5;
A is the highest weight = 5; and
N is the total number of respondents.

The selection of significant variables in the study used a benchmark of 0.60 points, which was determined by summing the weights and dividing by the total number of weighting items and highest weight, respectively: (1+2+3+4+5)/5/5 = 0.60. Thus, the criteria for evaluating CMWM with BIM that have an RII value of 0.60 or higher were classified as being significant, while those less than 0.60 are insignificant. This study adopted the method from [38] in anticipation that the use of 0.60 as a benchmark will effectively embrace all the significant criteria in terms of their usage. Similarly, a benchmark of 3.00 was utilised for a significant mean score value where the analysis was based on mean score computation such that (1+2+3+4+5)/5 = 3.00. The hypotheses were tested using the Kruskal Wallis H test to determine the consistency in the ranking of the variables by the three groups of AEC professionals surveyed as stratified by the study. The decision rule is that a p-value of 0.05 or less indicates strong evidence against the null hypothesis. Therefore, the test will only prove statistically insignificant if the computed p-value is greater than the critical p-value (0.05).

2.1 Ethical Issues

In carrying out this study, the informed consent of the respondents was sought and obtained. The respondents were made to be aware of their choice to freely participate or free to decline or withdraw in the survey. The respondents' privacy and persons were adequately respected, and their right to anonymity was assured and ensured in the study. The data collected from the respondents via the questionnaire were properly and rightly collected and adequately safeguarded from getting into the wrong hand to ensure confidentiality. All materials used in the research were properly referenced; the study was carried out without the use of machinery and strictly supervised by the researcher. The analysed data were the actual views of the respondents. Also, the outcomes and benefits of the research were not exaggerated, with copyright laws duly observed.

3. RESULTS, FINDINGS, AND DISCUSSION

3.1 Demographic attributes of survey

Respondents

The demographic attributes of the surveyed respondents were analysed. Three hundred questionnaires were administered, but two hundred and seven (207) valid ones were returned, which constitutes the database for the analysis. The analysed questionnaires represented a sixty-nine percent (69%) response rate and deemed acceptable based on the submission of Fincham [39] that an approximate of 60% response rate should be anticipated in survey studies in the twenty-first century.

The breakdown of the respondents shows that 92.3% were male, on average, while the female was 7.7%, as presented in Figure 1. About 95% were Nigerian professionals, with 26% being Architects, 36% being Builders, 26% were Quantity Surveyors, and 23% being Engineers. Similarly, Figure 1 shows that the majority of the respondents (52%) are young, vibrant professionals under ten (10) years of experience while about 30% possessed between ten to twenty years of experience and a good number of 18% have been practicing for more than twenty years. The majority, about 66%, possessed a Bachelor's degree or its equivalent (HND) in their various professional educational training while 23% had a Master's degree, and only 6% had a Ph.D. degree. Twenty-nine percent (29%) were certified Architects affiliated with the Nigerian Institute of Architect, 31% were registered Builders affiliated with the Nigerian Institute of Building, % being chartered Engineers affiliated with the Nigerian Society of Engineers.

In contrast, 20% were registered Quantity Surveyors affiliated with the Nigerian Quantity Surveyor Registration Board. Approximately 8% of the respondents had attained the Fellowship cadre of their profession. Whereas 39% were in the status of Corporate membership, and fifty-three (53%) were of Graduate membership at the time of the survey.

The analysis of the demographic characteristics of the respondents revealed quite remarkable qualities and demonstrated a sense of high reliability in their judgments and opinions about the use of BIM for CMWM. It is worthy of note that the profile of the participants used for this survey revealed that they are familiar with the use of BIM for the delivery of building projects and the management of waste, as presented in Figure 2. A cumulative of 49% of the respondents were familiar with the use of BIM for about 2-5years. However, 13.45% already have knowledge of it for more than 5years. This finding is inconsistent with the conclusions of Abubakar *et al*. [40] that the knowledge of BIM as innovative technology is relatively new in the Nigerian construction industry.

The result derived in this study may be due to continuous professional development programmes embarked upon by the various AEC professional regulatory bodies over time and, more importantly, the influence of giant oil-producing firms within this study area who mostly insist on current international standards on their construction projects. This study, therefore, establishes appreciable improvement on the proportion of the AEC professionals conversant with the use of BIM, which is similar to a more recent study by [41] in the study area. Nonetheless, some of the participants of this survey who accounted for 37.5% were young professionals with less than one (1) year familiarity with BIM.

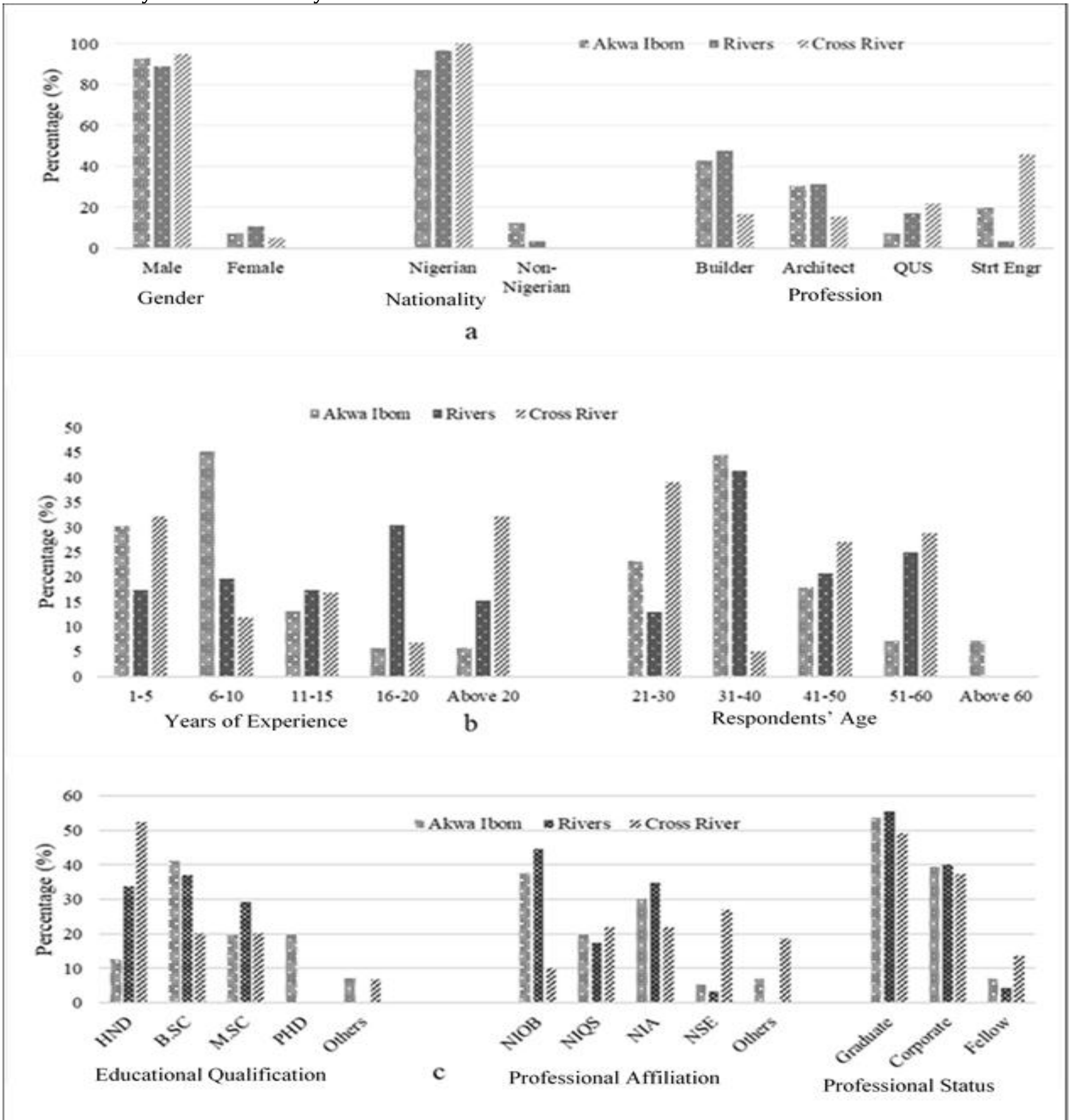

Figure 1: Respondents' Demographic Attributes

Notes: PhD = Doctorate Degree; MSc = Masters of Science Degree; BSc = Bachelor's Degree; HND = Higher National Diploma; NIOB = Nigerian Institute of Building; NIA = Nigerian Institute of Architects; NIQS = Nigerian Institute of Quantity Surveying; and NSE = Nigerian Society of Engineers; QUS = Quantity Surveyor; Strt Engr = Structural Engineer

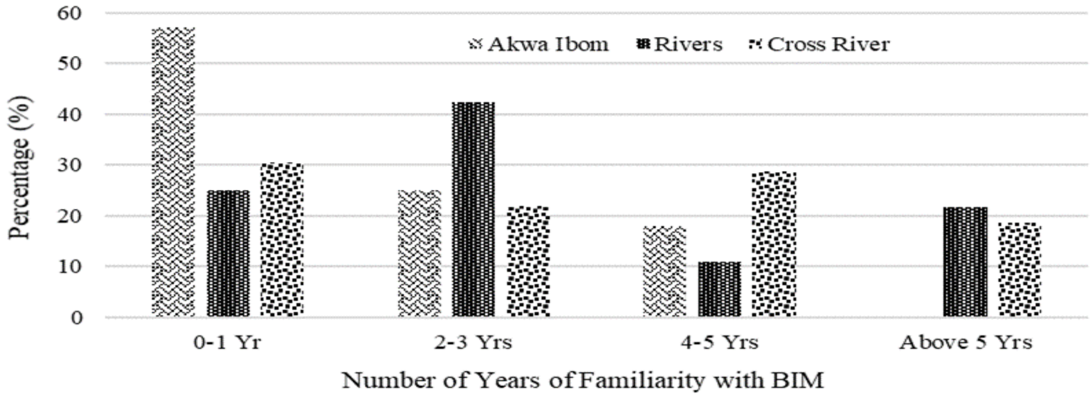

Figure 2: Respondents' Years of Familiarity with BIM

3.2 Level of use of BIM for evaluating construction wastes occurrence

Table 4 shows the outcome of the analysis for the level of use of BIM for evaluating construction waste occurrence on building sites in the study area. A benchmark of 0.600, which was derived from (1+2+3+4+5)/5/5 = 0.60, was used to identify the significant criteria. Based on the benchmark, thirteen (13) of the nineteen (19) evaluated criteria were found to be significant. The result revealed that the top seven criteria frequently used for evaluating the occurrence of waste through BIM to include "material standardisation" with RLU of 0.730, closely followed by "dimensional coordination,"; and "waste causes identification" with RLU values of 0.726 and 0.725 respectively. In the order is the fourth-ranked criterium ("decision support functionality") with an RLU value of 0.699, which is slightly higher than 0.691 identified with "schedule integration." The next criterium is "design out waste principles consideration" with RLU of 0.669 while "waste visualisation and reporting" is the seventh-ranked criterium with a score of 0.648. These highest ranked criteria are the ones commonly employed for assessing the occurrence of material waste as perceived by the participants of this study with relative use of about 65 percent or above. A value below the cut-off score indicates a low level of usage of such criterium for construction waste management in the study area. The five (5) least rated criteria are "waste prediction from design models,"; "interface for waste data collection,"; "robust materials database,"; "supply-chain engagement,"; and "procurement process coordination." The RLU values of these least-rated criteria range from 0.549 to 0.580, with the implication that they are not regularly used for enhancing the management of construction waste by the professionals in the study area.

Table -4: Level of Use of BIM for Evaluating CMWM

Criteria for Evaluating CMWM with BIM Technology	AKS		RVS		CRS		All States	
	RLU	Rank	RLU	Rank	RLU	Rank	RLU	Rank
Material standardisation	0.770	5	0.714	1	0.717	4	0.730	1
Dimensional co-ordination	0.803	1	0.662	4	0.771	2	0.726	2
Waste causes identification	0.784	3	0.685	2	0.717	5	0.725	3
Decision support functionality	0.798	2	0.677	3	0.784	1	0.699	4
Schedule integration	0.736	6	0.659	5	0.699	7	0.691	5
Design out waste principles consideration	0.713	9	0.601	7	0.735	3	0.669	6
Waste visualisation and reporting	0.603	16	0.633	6	0.712	6	0.648	7
Sufficient waste data collection	0.717	8	0.549	9	0.690	8	0.635	8
Accurate waste data capture	0.722	7	0.564	8	0.663	12	0.635	9
Access to suppliers' database	0.779	4	0.509	18	0.676	9	0.630	10
Waste origin consideration	0.693	10	0.544	10	0.676	9	0.622	11
Real time waste analysis	0.646	12	0.466	19	0.672	11	0.616	12
Accurate waste estimation	0.689	11	0.520	13	0.636	14	0.599	13
Transparency in waste data collection	0.632	14	0.532	11	0.636	14	0.589	14
Waste prediction from design models	0.646	13	0.515	16	0.618	16	0.580	15
Interface for waste data collection	0.594	17	0.520	13	0.654	13	0.578	16
Robust materials database	0.622	15	0.526	12	0.600	17	0.573	17
Supply-chain engagement	0.594	18	0.520	13	0.595	18	0.562	18
Procurement process coordination	0.570	19	0.512	17	0.586	19	0.549	19

AKS = Akwa Ibom State; RVS = River State; CRS =Cross River State; RLU = Relative Level of Use

The highest-ranked criterium ("material standardisation") prevents material wastage, which may result from poor designs that require cutting of materials on sites due to complex configurations, inappropriate specifications, ambiguities in specifications, and the likes. Ensuring standardised materials are designed for and procured will save much of the avoidable waste at the construction stage. Dimensional coordination, which is ranked in the second position, as a tool helps to organise different building components manufactured independently into an integrated whole, and improves flexibility in the use of the components. It is explanatory that while recycling and reuse strategies of waste minimisation act as "end of the pipe" treatment of waste, dimensional coordination is precautionary and preventive as a valid measure of curbing the production of waste [42]. Many recent studies explained the benefits of BIM to include "waste causes identification," which is enhanced with the use of BIM as it promotes visualisation of the model in the early design phase, which prevents design errors that can result in reworks [10, 28].

Decision support functionality, as explained by [1, 8], is one of the criteria that would empower waste minimisation tools with the ability to assist designers in understanding and visualising the impact of design changes in real-time, consequently supporting decisions by providing recommendations for the choice of strategies and subsequently revealing avenues for significant waste reduction. The benefit of integrating scheduling, with the help of 3D models, enhances estimation of duration, resource capacities, and quantities automatically to determine the correct duration of the work and work packages to complete an individual task [1]. It enables the internal content of an individual activity to become more transparent and easily accessible [43], which corroborates the studies of Sacks *et al*. [44] that a BIM-based visualisation user interface offers process transparency and identification of work packages and their relationships.

However, in this study, criteria such as "accurate waste estimation," "transparency in waste data collection," "waste prediction from design models," and "interface for waste data collection" are rated low based on the benchmark of 0.600 indicating a low level of use. Judging from the overall ratings of the criteria considered by this study, it was established that the level to which BIM is used for construction waste management in the study area is relatively low as compared with the ratings obtained by a similar study of the UK's AEC professionals by [11]. Whereas BIM is established to be frequently used for proper specifications and material selection, material standardisation and dimensional coordination to curb the issues of waste in construction, but this is yet to be fully realised in the study area.

3.3 Test of differences among the selected states on the use of BIM for CMWM

Table 5 presents the outcome of the test of differences in the level of use of BIM for evaluating construction waste occurrences among the selected States in the study area. Kruskal Wallis H test was used in the Statistical Package for Social Scientist (SPSS). The decision rule to reject the hypothesis is that when the p-value > 0.05, the test fails to reject the hypothesis; however, if the p-value ≤ 0.05, the test rejects the hypothesis. The result yielded a p-value of 0.001, which is less than the 0.05, signifying significant variation in the level of use of BIM for CMWM among the selected States and indicating a lack of agreement among the three groups. The result led to the rejection of the null hypothesis and the conclusion that there is a significant variation in the levels of BIM usage for evaluating construction waste occurrence among the selected States. This result reinforces the assertion that the adoption of BIM by AEC professionals in the study area for project delivery has not gained ground.

Table -5: Test of Differences on the Use of BIM for CMWM among the Selected States

State Identity	Mean Rank	Chi-Square	df	Asymp. Sig.	Decision
Akwa Ibom State	38.48	20.075	2	0.001	Reject
Rivers State	16.25				
Cross River State	36.78				

3.4 Potentials of BIM for CMWM on Building Sites

Table 6 presents the analysis of the responses of the professionals on the potentials of BIM for construction material waste management (CMWM). The result shows that "3D coordination of building models to reduce waste (clash detection)" is the first BIM tool rated by the respondents for managing waste while "detect illogical designs"; was ranked in the second position. The third-ranked BIM tool CMWM is "3D control and planning" with a mean score of 3.275 while "site utilization planning" was rated fourth with a mean value of 3.242.

The fifth-ranked tool is "computer-aided visualisation and simulation of waste performance,"; while the sixth-ranked variable is "detailing,"; and "quantity take-off (cost estimation)" was the seventh-ranked BIM tool for waste management in this survey study. With a benchmark of 3.00 mean score fixed for the identification of essential BIM tools for CMWM, twenty-four (24) of the twenty-eight (28) BIM tools presented to the surveyed participants were identified to affect the management of construction waste significantly. The three (3) least BIM tools for CMWM include "digital fabrication"; "computer-aided visualisation and simulation of waste performance"; and "early supply-chain integration for sourcing and supply for waste management decisions."

The results derived in this study are consistent with the phenomena in some existing literature [13, 18, 28, 29, 45, 46], where some of these BIM tools were outlined with various potencies in solving construction waste problems on sites. For instance, "clash detection" being the topmost ranked BIM tool in this study can reduce a good number of design errors and rework, thus plummeting the quantity of construction waste on building sites by up to 15% [28]. Suffice it to say that all design errors do not necessarily lead to rework, but those that have the tendencies of leading to rework should be detected with BIM technology using 3D coordination of building models, visualization, and simulation to curb wastes. Nonetheless, rework has been identified as a significant cause of construction material waste in this study area by similar studies [5, 47, 48].

Table -6: Potentials of BIM for CMWM on Building Sites

Potentials of BIM for CMWM	AKS			RVS			CRS			All States		
	Sum	Mean	Rank	Sum	Mean	Rank	Sum	Mean	Rank	Sum	Mean	Rank
3D Coordination of building models to reduce waste (clash detection)	175	3.125	4	304	3.304	12	222	3.763	1	701	3.387	1
Detect illogical designs	171	3.054	7	321	3.489	3	197	3.339	5	689	3.329	2
3D Control and planning	159	2.839	18	348	3.783	1	181	3.068	16	688	3.324	3
Site utilization planning	185	3.304	1	284	3.087	24	209	3.542	2	678	3.275	4
Computer aided visualisation and simulation of waste performance	170	3.036	9	295	3.207	18	206	3.492	3	671	3.242	5
Detailing	151	2.696	23	341	3.707	2	177	3.000	19	669	3.232	6
Quantity take-off (cost estimation)	168	3.000	11	305	3.315	11	195	3.305	7	668	3.227	7
Identify solutions to collisions	161	2.875	17	311	3.38	6	193	3.271	9	665	3.213	8
Detect omissions	166	2.964	13	311	3.38	7	185	3.136	13	662	3.198	9
Create BIM Models	162	2.893	15	304	3.304	13	194	3.288	8	660	3.188	10
Perform constructability review	177	3.161	3	304	3.304	14	179	3.034	17	660	3.188	11
Improved coordination and communication	168	3.000	12	297	3.228	17	191	3.237	12	656	3.169	12
Construction system design	152	2.714	22	320	3.478	4	183	3.102	14	655	3.164	13
Record modelling	175	3.125	5	274	2.978	26	201	3.407	4	650	3.14	14
Phase planning (4D simulation)	158	2.821	20	313	3.402	5	178	3.017	18	649	3.135	15
Interoperability among waste management tools and BIM software	159	2.839	19	307	3.337	10	182	3.085	15	648	3.13	16
Detect discrepancies	184	3.286	2	299	3.25	15	162	2.746	26	645	3.116	17
Automatic generation of waste related documents	156	2.786	21	289	3.141	22	196	3.322	6	641	3.097	18
Perform O & M Review	171	3.054	8	299	3.25	16	170	2.881	25	640	3.092	19
Support for whole-life waste analysis	172	3.071	6	294	3.196	19	174	2.949	23	640	3.092	20
Modify BIM Models	162	2.893	16	294	3.196	20	175	2.966	22	631	3.048	21
Use of 3D printing for prefabrication	149	2.661	24	289	3.141	23	192	3.254	10	630	3.044	22
Improved materials classification methods	170	3.036	10	265	2.88	27	192	3.254	11	627	3.029	23
Existing conditions modelling	137	2.446	27	311	3.38	8	176	2.983	21	624	3.015	24
Generate BIM Reports	149	2.661	25	284	3.087	25	177	3.000	20	610	2.947	25
Digital Fabrication	138	2.464	26	309	3.359	9	157	2.661	27	604	2.918	26
Support for waste management innovations	135	2.411	28	291	3.163	21	174	2.949	24	600	2.899	27
Early supply-chain integration for sourcing and supply for waste management decisions	166	2.964	14	259	2.815	28	152	2.576	28	577	2.787	28

AKS = Akwa Ibom State; RVS = River State; CRS = Cross River State

Therefore, it is pertinent to employ the use of BIM by AEC professionals around this study area to solve the problems of CMWM decisively. It has been argued that the detection of illogical design, which is ranked in the second position by this study, is relatively tricky without the use of BIM technology, yet it is usually the cause of design error [28]. More than 800 design errors were detected by BIM-based design validation in two BIM-based projects in South Korea in the study reported by [46]. Project delays, cost overruns, low quality, and rework generation were identified to be dependent upon design errors arising from illogical design. The performance potential of BIM-assisted identification of individual design errors was examined by [45], and the total cost of design errors leading to schedule delay was found to be exorbitantly high.

The third-ranked BIM tool in this study ("3D control and planning") exerts its influence on CMWM at the preconstruction stage of AEC projects. The number of layout errors can be decreased if a BIM model is integrated with real-world coordinates to decrease the amount of rework by obtaining the precise control points on site. Close related to "3D control and planning" is "site utilization planning," which is ranked fourth in this study. The use of BIM for "site utilisation planning," together with quantity take-off, enables the reduction of some unnecessary and inappropriate material handling. Past studies have advised that site managers should ensure that the wastes associated with the handling of materials on site are kept to a minimum coupled with continuous communication among the parties, which is enhanced by BIM [47, 49], especially in developing countries where manual material handling is still prevalent. Improved construction planning and management using BIM have been acknowledged to contribute positively to a significant reduction of C&D waste by avoiding rework and unnecessary material handling and by efficiently using raw materials based on accurate measurement for material ordering, layout, and cutting [13]. The task of monitoring the flow of materials until the connected construction work is completed is an essential practice that prevents waste either in the form of material usage, theft, or vandalism [50]. Summarily, the results show that the responding participants in this survey acknowledged the use of BIM for visualisation and simulation for improving the management of construction waste and quantity estimation and detailing. Therefore, BIM usage in AEC project implementation is essential to enable effective CMWM coordination, which was equally observed in the study of [16].

3.5 Testing the differences on the potentials of BIM for CMWM among the selected States

Table 7 shows the result of the second hypothesis (H_{02}) tested for the differences in the potential of BIM for CMWM on construction sites among the selected States. The hypothesis result produced a p-value of 0.001 value, which is less than 0.05, which is the benchmark for the acceptance of the null hypothesis. Consequently, the study rejected the null hypothesis, and the alternative one that there is a significant variation in the potential of BIM for CMWM on building sites among the selected States was accepted. It shows that the professionals in the selected States possess varied opinions in their discernment towards the possibilities of BIM for waste management on building sites; hence, the inconsistencies in the ranking of the factors. Therefore, a conclusion was made that the potential of BIM for CMWM on construction sites among the selected States varied significantly.

4. CONCLUSIONS AND RECOMMENDATIONS

This study was conducted to examine the level of use of BIM and the potentials of BIM for CMWM among the AEC professionals in the South-South region of Nigeria to reduce the occurrence of construction material waste. The findings revealed that material standardisation, dimensional coordination, and waste causes identification were foremost criteria for using BIM by the professionals in their efforts to reduce waste. The potentials of BIM, as perceived by the participants of this study, lie mostly in "clash detection" to reduce waste; detecting illogical designs; and 3D control and planning in the study area. The tests of hypotheses for the level of use of BIM and the potentials it offers for CMWM among the selected States varied significantly, showing that there is no congruency neither in the use of BIM nor in the knowledge of its potentials among the study participants. The study concluded that there is a significant variation in the levels of BIM usage among the selected States for evaluating construction waste occurrence, as well as the potentials of BIM for CMWM among the AEC professionals. This variation could be as a result of the low level of usage earlier observed and low familiarity with the BIM tools among the professionals in the selected States. It was established and concluded that the level to which BIM is used for construction waste management in the study area is relatively low. Therefore, this study recommends the pertinent use of BIM by AEC professionals to solve the problems of CMWM decisively and for project delivery in the study area to derive the benefits it offers.

ACKNOWLEDGEMENTS

The authors acknowledge the AEC professionals who participated in the pilot study and the field survey that produced data for this work, including the research assistants that offered supports.

REFERENCES

[1] S. Seyis, "Pros and Cons of Using Building Information Modelling in the AEC Industry," Journal of Construction Engineering and Management, vol. 145, issue 8, 2019, pp. 04019046-1 – 04019046-17. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001681

[2] A. M. Ahmad, P. Demian, and A. D. F. Price, "BIM Implementation Plans: A Comparative Analysis," In Smith, S. D. (ed.), Proceedings of 28th Annual Conference of Association of Researchers in Construction Management (ARCOM), 3-5 September 2012, Edinburgh, UK, pp. 33-42.

[3] C. M. Eastman, C. Eastman, P. Teicholz, R. Sacks, and K. Liston, BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers, and Contractors. Canada: John Wiley and Sons, 2011.

[4] I. Saidu, and W. Shakantu, A Study of the Relationship Between Material Waste and Cost Overrun in the Construction Industry. Proceedings of the 9th CIDB Postgraduate Conference: Emerging Trends in Construction Organisational Practices and Project Management Knowledge Area, February 2-4, 2016, *Cape Town, South Africa,* pp. 124-134.

[5] T. O. Adewuyi, and I. A. Odesola, "Factors Affecting Material Waste on Construction Sites in Nigeria," Journal of Engineering and Technology, vol. 6, issue 1, pp. 82-99. https://journal.utem.edu.my/index.php/jet/article/view/237

[6] J. Jayamathan, and R. Rameezdeen, "Influence of Labour Arrangement on Construction Material Waste Generation," Structural Survey, vol. 32, issue 2, 2014, pp. 76-88. http://dx.doi.org/10.1108/SS-09-2012-0026

[7] Swinburne, J., Udeaja, C.E., and Tait, N. (2010). Measuring Material Wastage on Construction Sites: A Case Study of Local Authority Highway Projects. *Built and Natural Environment Research Papers*, vol. 3, issue 1, pp. 31-41.

[8] OO. Akinade, L.O. Oyedele, K. Munir, M. Bilal, S. O. Ajayi, H. A. Owolabi, H. A. Alaka, and S. A. Bello, "Evaluation Criteria for Construction Waste Management Tools: Towards A Holistic BIM," International Journal of Sustainable Building Technology and Urban Development, vol. 7, issue 1, 2016, pp. 3-21. https://doi.org/10.1080/2093761X.2016.1152203

[9] Z. Liu, M. Osmani, P. Demian, and A. Baldwin, "The Potential Use of BIM to Aid Construction Waste Minimisation," Proceedings of the CIB W78-W102 International Conference, 26th-28th October 2011, Sophia Antipolis, France, paper 53.

[10] A. Ahankoob, S. M. Khoshnava, R. Rostami, and C. Preece, "BIM Perspectives on Construction Waste Reduction" Proceedings of Management in Construction Research Association (MiCRA), Postgraduate Conference, Malaysia, January 2012, pp. 195–199.

[11] O. O. Akinade, L. O. Oyedele, S. O. Ajayi, M. Bilal, H. A. Alaka, H. A. Owolabi, and O. O. Arawomo, "Designing Out Construction Waste Using BIM Technology: Stakeholders' Expectations for Industry Deployment," Journal of Cleaner Production, vol. 180, 2018, pp. 375-385. https://doi.org/10.1016/j.jclepro.2018.01.022

[12] Y. G. Amuda, R.T. Adebiyi, and I. B. Muhammad, "BIM Awareness and Adoption by Construction Organizations in Nigerian," USEP: Journal of Research Information in Civil Engineering, vol. 15, issue 2, 2018, pp. 2205-2224.

[13] J. Won, and J. C. P. Cheng, "Identifying Potential Opportunities of Building Information Modeling for Construction and Demolition Waste Management and Minimization," Automation in Construction, vol. 79, 2017, pp. 3–18. http://dx.doi.org/10.1016/j.autcon.2017.02.002

[14] M. Bilal, L. O. Oyedele, J. Qadir, K. Munir, O. O. Akinade, S. O. Ajayi, H. A. Alaka, and H. A. Owolabi, "Analysis of Critical Features and Evaluation of BIM Software: Towards A Plug-in for Construction Waste Minimization Using Big Data," International Journal of Sustainable Building Technology and Urban Development, vol. 6 issue 4, 2016, pp. 211-228. https://doi.org/10.1080/2093761X.2015.1116415

[15] P. Walmikey, and P. Kulkarni," Construction Waste Management Through the Applications of BIM," International Journal of Advanced Research in Science and Engineering, vol. 5, Special issue 1, 2016, pp. 193-200.

[16] J. C. P. Cheng, J. Won, and M. Das, "Construction and Demolition Waste Management Using BIM Technology," Proceedings of 23rd Annual Conference of the International Group for Lean Construction, Perth, Australia, July 29-31, 2015, pp. 381-390.

[17] I. O. Onungwa, and N. Uduma-Olugu, "Building Information Modelling and Collaboration in the Nigerian Construction Industry," Journal of Construction Business and Management, vol. 1, issue 2, 2017, 1-10.

[18] R. Sacks, L. J. Koskela, B. A. Dave, and R. Owen, "The Interaction of Lean and Building Information Modelling in Construction," Journal of Construction Engineering and Management, vol. 136, issue 9, 2010, pp. 968-980. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000203.

[19] B. Abdal Noor, and S. Yi, "Review of BIM Literature in Construction Industry and Transportation: Meta-analysis," Construction Innovation, vol. 18, issue 4, 2018, pp. 433-452. https://doi.org/10.1108/CI-05-2017-0040.

[20] G. Aouad, S. Wu, A. Lee, and T. Onyewobi, Computer-Aided Design Guide for Architecture, Engineering and Construction. London: Routledge, Taylor, and Francis, 2014.

[21] A. Agapiou, L. E. Clausen, R. Flanagan, G. Norman, and D. Notman, "The Role of Logistics in the Materials Flow Control Process," Construction Management and Economics, vol. 16, issue 2, 1998, pp. 131-137. https://doi.org/10.1080/014461998372420

[22] N. Lu, and T. Korman, "Implementation of Building Information Modeling (BIM) in Modular Construction: Benefits and Challenges," Construction Research Congress, Banff, 8-10 May 2010, pp. 1136-1145. http://doi.org/10.1061/41109(373)114

[23] T. O. Adewuyi, and I. A. Odesola, "Material Waste Minimisation Strategies among Construction Firms in South-South, Nigeria," International Journal of Sustainable Construction Engineering and Technology, vol. 7, issue 1, 2016, pp. 11-29. https://publisher.uthm.edu.my/ojs/index.php/IJSCET/article/view/1174

[24] J. Ayarkwa, K. Z, Agyekum, and E. Adinyira, Exploring Waste Minimization Measures in the Ghanaian Construction Industry.," Built Environment Journal, vol. 8, issue 2, 2011, pp. 22-30.

[25] G. A. Bekr, "Study of the Causes and Magnitude of Wastage of Materials on Construction sites in Jordan," Journal of Construction Engineering, 2014, pp. 1-6. http://dx.doi.org/10.1155/2014/283298

[26] T. O. Adewuyi, G. I. Idoro, and I. J. Ikpo, "Empirical Evaluation of Construction Material Waste Generated on Sites in Nigeria," Civil Engineering Dimension, vol. 16, issue 2, 2014, pp. 96-103. https://doi.org/10.9744/ced.16.2.96-103

[27] B. A. G. Bossink, and H. J. H. Brouwers, "Construction Waste: Quantification and Source Evaluation," Journal of Construction Engineering and Management, vol. 122, issue 1, 1996, pp. 55-60. https://doi.org/10.1061/(ASCE)0733-9364(1996)122:1(55)

[28] J. Won, J. C. Cheng, and G. Lee, "Quantification of Construction Waste Prevented by BIM-Based Design Validation: Case Studies in South Korea," Waste Management, vol. 49, 2016, pp. 170 - 180. http://dx.doi.org/10.1016/j.wasman.2015.12.026

[29] Z. Liu, M. Osmani, P. Demian, and A. Baldwin, "A BIM-aided Construction Waste Minimisation Framework," Automation in Construction, vol. 59, 2015, pp. 1-23. http://dx.doi.org/10.1016/j.autcon.2015.07.020

[30] D. Parmar, J. R. Pitroda, and S. Malek, "Use of BIM (Building Information Modelling) as an Integrated Tool to Plan, Design, and Manage Critical Construction Projects," International Journal of Advance Research and Innovative Ideas in Education (IJARIIE), vol. 3, issue 1, 2017, pp. 1145-1153.

[31] P. E. Love, Z, R. Lope, and D. J. Edwards, "Reviewing the Past to Learn in the Future: Making Sense of Design Errors and Failures in Construction," Structure and Infrastructure Engineering: Maintenance, Management, Life-Cycle Design and Performance, vol. 9, issue 7, 2013, pp. 675-688. http://dx.doi.org/10.1080/15732479.2011.605369

[32] J. K. Adafin, O. Daramola, and E. O. Ayodele, "A Study on Material Control Strategies in Some Selected Construction Firms in Nigeria," Continental Journal of Applied Sciences, vol. 1, 2010, 62–72.

[33] S. P. Teoh, O. Abdelnaser, and H. K. Abdul, "Material Wastage in Malaysian Construction Industry" International Conference on Economics and Administration, Faculty of Administration, University of Bucharest, Romania, 2009, pp. 257-264.

[34] S. Azhar, A., Nadeem, J. Y. N. Mok, and B. H. Y. Leung, "Building Information Modelling (BIM): A New Paradigm for Visual Interactive Modelling and Simulation for Construction Projects. First International Conference on Construction in Developing Countries, Karachi, Pakistan, 2008, pp. 435–446.

[35] H. Taherdoost, "Validity and Reliability of the Research Instrument: How to Test the Validation of a Questionnaire/Survey in a Research," International Journal of Academic Research in Management (IJARM), vol. 5, issue 3, 2016, pp. 28-36.

[36] C. H. Lawshe, "A Quantitative Approach to Content Validity," Personnel Psychology, vol. 28, 1975, pp. 563-575.

[37] H. Taherdoost, H. (). Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research," International Journal of Academic Research in Management, vol. 5, issue 2, 2016, pp. 18-27.

[38] D. I. Ikediashi, S. O. Ogunlana, and P. Boateng, "Determinants of Outsourcing Decision for Facilities Management (FM) Services Provision, "Facilities, vol. 32, issue 9/10, 2014, pp. 472 – 489. http://dx.doi.org/10.1108/F-06-2012-0047

[39] J. E. Fincham, "Response Rates and Responsiveness for Surveys, Standards, and the Journal," American Journal of Pharmaceutical Education, vol. 72, issue 2, 2008, pp. 1-3.

[40] M. Abubakar, Y. M. Ibrahim, D. Kado, and K. Bala, "Contractors Perception of the Factors Affecting Building Information Modeling (BIM) Adoption in the Nigerian Construction Industry," Computing in Civil and Building Engineering, 2014 167–178. https://doi.org/10.1061/9780784413616.022

[41] D. O. Ebiloma, and M. G. Oladokun, "The Use of Binary Logistics Regression on the Awareness Level of Building Information Modelling," International Journal of Innovation and Sustainability, vol. 1, 2017, pp. 44-55.

[42] S. O. Ajayi, L. O. Oyedele, M. Bilal, O. O. Akinade, H. A. Alaka, H. A. Owolabi, and K. O. Kadiri, "Waste Effectiveness of the Construction Industry: Understanding the Impediments and Requisites for Improvements," Resources, Conservation and Recycling, vol. 102, 2015, pp. 101–112. https://doi.org/10.1016/j.resconrec.2015.06.001

[43] T. Dang, and H. J. Bargstädt, "4D Relationships: The Missing Link in 4D Scheduling," Journal of Construction Engineering and Management, vol. 142, issue 2, 2016, pp. 04015072. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001007.

[44] R. Sacks, M. Treckmann, and O. Rozenfeld, "Visualization of Work Flow to Support Lean Construction," Journal of Construction Engineering and Management, vol. 135, issue 12, 2009, pp. 1307–1315. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000102.

[45] N. Ham, S. Moon, J. H. Kim, and J. J. Kim, "Economic Analysis of Design Errors in BIM-Based High-Rise Construction Projects: Case Study of Haeundae L Project," Journal of Construction Engineering and Management, vol. 144, issue 6, 2018, pp. 05018006-1 - 05018006-13. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001498

[46] J. S. Won, and J. Y. Kim, "Analysis of the Relations between Design Errors Detected during BIM-based Design Validation and their Impacts Using Logistic Regression," Journal of the Korea Institute of Building Construction, vol. 17, issue 6, 2017, pp. 535-544. https://doi.org/10.5345/JKIBC.2017.17.6.535.

[47] T. O. Adewuyi, and M. G. Oladokun, "Causes and Sources of Material Waste in Building Construction Projects in

Akwa Ibom State," Journal of Environmental Design, vol. 10, issue 1, 2015, pp. 1-13.

[48] T. O, Adewuyi, and M. Otali, "Evaluation of Causes of Construction Material Waste: Case of Rivers State, Nigeria," Ethiopian Journal of Environmental Studies and Management, vol. 6. Supplement issue, 2013, pp. 746-753. https://doi.org/10.4314/ejesm.v6i6.5S.

[49] J. P. Spillane, L. O. Oyedele, J. Von Meding, A. Konanahalli, B. E. Jaiyeoba, and I. K. Tijani, "Challenges of UK/Irish Contractors Regarding Material Management and Logistics in Confined Site Construction," International Journal of Construction Supply Chain Management, vol. 1, issue 1, 2011, pp. 25-42. https://doi.org/10.14424/ijcscm101011-25-42

[50] T. O. Adewuyi, and M. G. Oladokun, "Relationship between Material Management and Material Waste on Sites in Nigeria," Nigerian Journal of Construction Technology and Management, vol. 13, issue 1&2, 2015, pp. 1- 15.